Design of a Mulitple Input Single Output DC-DC Converter for the DC House Project

By

Chad Santos
Siby James

Senior Project

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University

San Luis Obispo

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Abstract

This senior project report describes the design and further development of the MISO (multiple input, single output) circuit. The MISO circuit harnesses power from four separate renewable energy sources (hydro, solar, wind and man) and converts it into a single DC output voltage. Though this circuit has been initially designed and tested in previous years, it was only developed enough to use as a test circuit. Further implementation will allow for the MISO to be available in a more practical setting. Professor Taufik will then take the newly designed MISO circuit to implement in a house in Indonesia.

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Chapter 1

81% of the energy in the world is generated through the use of fossil fuels. In contrast, only 12.8% of the world's energy is produced through means of renewable sources[1]. Though renewable energy has taken great strides in the past decade, the abundance of fossil fuel usage is still staggering. Continuing to use fossil fuels creates several disadvantages and health hazards for the earth. The burning of fossil fuels leads to excess carbon dioxide produced in the atmosphere. These carbon dioxide emissions lead to greenhouse gases that inevitably results in global warming. Not only does this lead to drastic temperature and climate changes, it also creates holes in the earth's protective ozone layer. Ultra violet rays that penetrate our ozone layer can lead to dangerous consequences for the human population such as skin cancer. Finally, the continuous use of fossil fuels will eventually lead to a depletion of fossil fuels since they are a limited resource. On the other hand, renewable sources of energy will never run out.

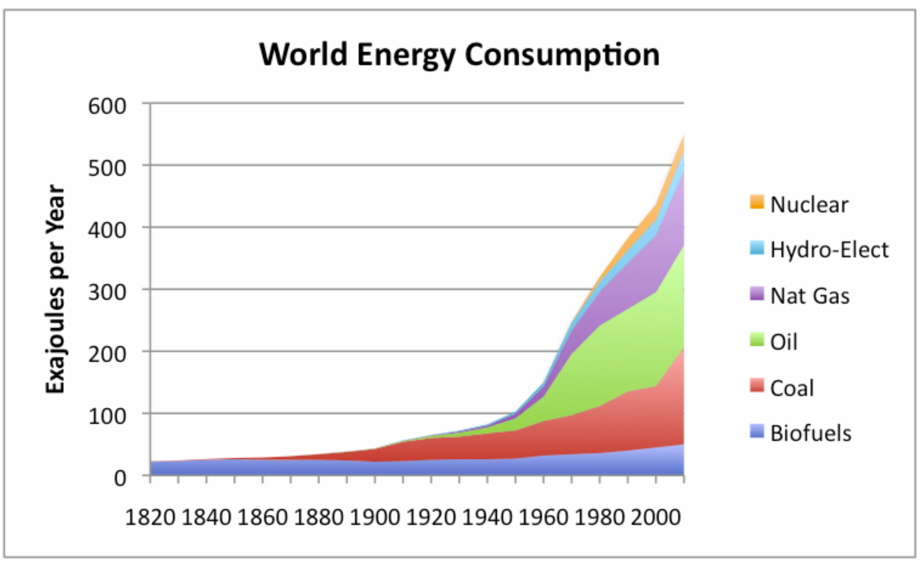

Figure 1-1: Informational graph detailing energy use from years 1820-2010[2]

Solar, wind and hydro resources are all readily available to use without having to worry about conservation of sources. Renewable energy sources also help limit the environmental damages that are a result of burning fossil fuels. On a more ethical note, renewable energy sources can provide more rural areas with a means of energy generation. Fossil fuel energy generation is difficult to attain in rural areas, thus resulting in areas with little to no electricity. However, renewable energy sources are abundant in these areas, ideally providing an unlimited source of energy. The use of renewable energy in rural areas has several benefits that go beyond just electricity generation. Further use of energy means the further development of the industrialization for these areas. Most of the populations that live in these areas are living at or below the poverty line. The generation of electricity can result to more job opportunities and thus better chances at success.

All energy on the planet comes from solar energy in one form or another. For example, Humans and plants rely on the sun for warmth and food, while other organisms consume certain foods which gained energy from the sun. In the past few decades, the introduction of solar energy has brought forth a wave of companies supporting the use of solar energy in homes and industry. Photovoltaics (PV) is a simple method used to harness the sun's energy and create a usable form for consumers. In order to utilize the energy from this system it is necessary to have two components, an energy collector and storage unit. The collector is used to collect the sun radiation that falls on it and convert a fraction of it to other forms of energy (heat and electricity). The storage unit is used to store excess energy from the time when sunlight is most prominent to use during overcast skies or night.

Wind is an energy that can be utilized in any space regardless of the area. For hundreds of years, wind power has been used in various applications such as the sail boat and windmills. Although the classification of the strength and speed of wind is highly dependent on the weather, it can be considered an efficient and useful source of energy. The benefit of using wind power is that is an energy that will never run out, unlike coal and oil, as long as there is airflow within the space used. Another benefit of wind power comes from its environmentally friendly energy that is produced from the wind turbine. Unlike oil or coal, the material used to create the energy has no negative impact on the environment.

Hydro power is an unrecognized form of renewable energy that is slowly working its way into the world. Although certain parts of the world are industrializing very quickly, such as China and India, they neglect the impact of the energy they are using and the negative effects it has on the environment. The Hydro Power generator allows for water to be used in order to preserve resources, while generating electrical energy in a sustainable manner. The water is used by placing the generator in water. The turbine will the rotate and convert the kinetic energy into electrical energy without using any of the water.

Human power is the least used form of renewable energy due to the amount of time and effort needed to produce a usable amount of energy. However, there are ways to make these tedious process more efficient. For example, exercise machines in gyms that generate kinetic energy when used can be converted into electrical energy. This concept can be used to develop usable renewable energy sites that generate electricity as a by-product of recreational activities.

Introducing rural areas to this type of technology is the first step in developing and integrating it into their lives. The electricity produced by renewable energy opens the doors to countless opportunities in developing countries. This is where the DC house project comes in. The DC house will be designed as an option for rural areas that do not have access to electricity. In order for this to become a reality, the DC house will need to rely on all forms of renewable energy stated above.

Chapter 2: Background

The DC house is designed to be a fully functional and operational house with its sole source of energy being generated from renewable energy sources. The DC house takes in four separate renewable energy sources and converts it into a single DC output used to power the house. The four sources of energy are solar, hydro, wind, and mechanical. Having four separate sources allows for one or more of the sources to be unavailable, yet still getting power from the other remaining sources.

Prior to the DC house project, the predominant use of renewable energy came in the form of solar energy. By introducing multiple sources of renewable energies, it gives many more options in the use of renewable energy. The other available sources of power for the DC house provide an alternate source, when certain sources are not providing enough voltage. For example on a cloudy day, the solar energy would not provide enough voltage to power the house. but the hydro, solar, and man power of the DC house would be adequate substitutes. In application of the DC house, this provides houses in rural areas with a greater access to electricity, thus giving more opportunity for income and employment.

The current DC house started as a project at Cal Poly, San Luis Obispo in 2010 and has been through 4 Phases to reach its near completion. The primary motivation of the DC House project is to provide electricity for people living in rural areas especially those in remote areas and secluded islands using renewable energy sources and human-powered generators.

Phase 1 of the DC house concluded in 2011 and dealt with the initial results of studies on DC house electrical system designs, generator systems, and the main dc-dc converter. One of the main systems included in the DC house was the design and development of a more efficient and reliable PV system. This included the creation of a more efficient DC-DC converter so that less losses occur and more power could be produced for the house. The converter was designed to have an output of 24V and 8.3A[6]. Similarly, a system in which energy was harvested through the use of flowing water was designed in the same year[1]. Like the PV input discussed previously, the hydro system was designed to efficiently harness 12V before a step-up DC-DC converter eventually converts it to 24V. Systems that harness wind energy were also developed in this year that also generated 12V, each with its corresponding step-up converter[5]. This systems were vital in trying to develop a house that ran strictly on DC energy. The mechanical (man) powered system was not yet designed.

Phase 2 of the DC house was completed in June 2012 and involved the design and completion of a physical DC house model on campus at Cal Poly, along with the DC light bulb that goes within the house. The DC house, as of June 2015, has been remodeled with a fresh layer of paint as well as has solid flooring. The aesthetic portion of the house is just as important as the electrical portion because the goal of the project is to create a house that someone can live in.

Phase 3 of the DC house concluded in June 2013 and involved the design and development of the first MISO converter that would eventually combine all the renewable energy inputs and convert it into a single DC output. Also developed in phase 3 was a mechanical system that could be used to harvest another renewable energy source. The mechanical system was designed to be a merry-go-round and swing set. This provided a source of energy that could be harnessed through children playing and not physical labor. Similar to the previously designed renewable energy systems, the swing set and merry-go-round were developed to have a 12V output after a DC-DC converter is used. The MISO circuit was initially designed using a full bridge DC-DC topology which chooses the highest input of the four renewable energy sources (using an or diode) and steps it up from 24V to 48V. This circuit proved to be successful in producing the desired output. However, this design was not marketable, nor reproducible as several components would overheat and some components were custom wound. Because the MISO is what interfaces the input and output of the DC house, it is crucial to try and produce a more manufacturable circuit.

Phase 4 is currently on-going and is the final phase of the DC house project. The MISO circuit is under redesign, as several universities would like to implement their own DC house on campus. In order to do so, the MISO must use more commercially available components (e.g. transformers, inductors, diodes, etc). The goal of this senior project is to redesign the original MISO design using a more available software, along with producing a board using solely commercially available components, while maintaining the properties of the original circuit. Producing a more marketable circuit also involved the use of circuit protection (previously not incorporated).

Chapter 3: Design Requirements

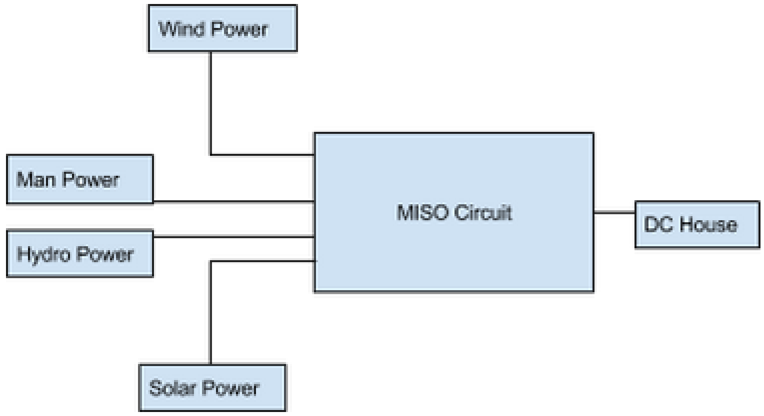

Figure 3.1: Level 0 block diagram describing high level functionality of MISO Circuit

Table 3.1: Input Specifications

Input Source	Each Source Pre-Regulated using DC-DC converter	Maximum Input Power	MOS-FET Turn On Voltage to allow input to flow through
Solar Power	24V	288W	9V
Hydro Power	24V	288W	9V
Wind Power	24V	288W	9V
Man Power	24V	288W	9V

Each input source is assumed to be pre-regulated through use of a DC-DC step up converter to 24V meaning each source can provide, independently, 24V to the transformer and thus provide 48V to the output. If, for example, each source were providing 24V, the output will only take from one source. The remaining three sources will not send its voltage to the house, but instead it will charge a generator that can be used in case of emergency.

IC Power

The IC's throughout the MISO mostly are powered by a 12V input voltage. Without this 12V power supply, much of the board will not function to provide signals to MOSFETs which drive the output of the MISO. In order to obtain a 12V voltage from the 24V input a step-down DC-DC Converter (Buck) was used to provide power to the ICs.

Input Functionality

The input of the MISO has four separate input sources. These input sources are connected to the MISO through the use of N-channel MOS-FETs. The MOS-FET only allows current to the MISO circuit when the respective input source reaches 9V with reference to ground. Once 9V is reached, the input then gets sent to the full-bridge converter and sent to the output. The full bridge converter recognizes the amount of input being sent in and will not over send voltage to the converter. Any excess voltage supplied from each source will be used to charge an emergency generator. The level 1 block diagram can been seen in Figure 2 below. This will better describe the input functionality. The reason there is an N channel MOS-FET with ideal diode connected to each input is because if any input source were to be shorted and not functional, there will be no reverse bias current being sent back into the source. This helps protect the input.

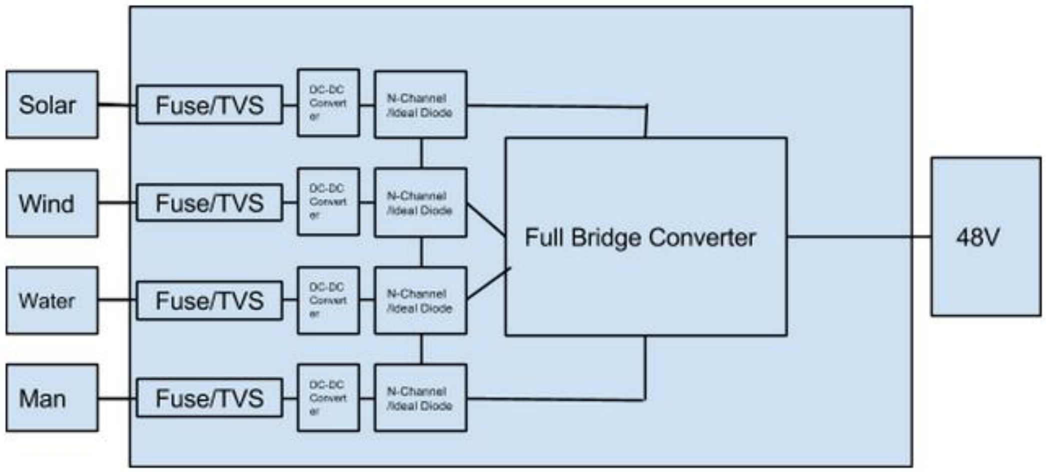

Figure 3.2: Level 1 Block Diagram of MISO Circuit

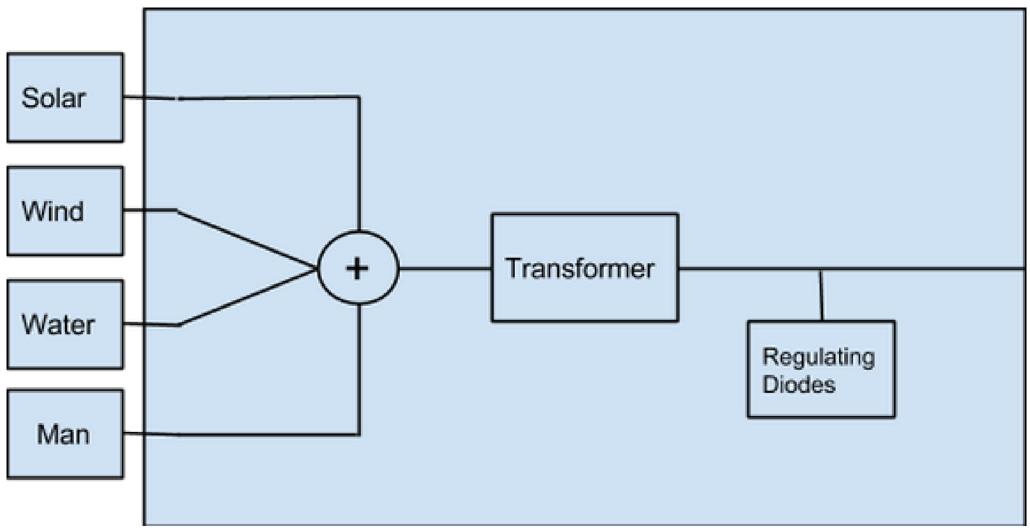

Figure 3.3: Level 1 Block Diagram of Full Bridge Converter

Figure 3.3 shows the inputs being sent to the transformer. The transformers primary function is to step up the voltage from 24V to the desired 48V. The transformer assists with DC isolation between the input and output. Proper sizing of the transformer allow for less voltage and current stress on surrounding components.

The regulating diodes seen in Figure 3.3 are used to create a DC voltage from the waveform coming out of the transformer. Since we are sending a square wave through the transformer. The diodes used for regulating are fast recovery diodes which are generally used for conversion of AC to DC. Unfortunately, the fast diodes have higher conduction losses than regular rectifier diodes, but serve this application well by regulating the transformer waveform

Output Specifications

Table 3.2: Output Requirements of MISO

Output Power	288W
Input Power	Dependant on input source
Efficiency	>80%
Output Voltage	48V
Peak to Peak Ripple Voltage	<5%
Linear Regulation	<3%
Load Regulation	<5%
Temperature of Components	<70 degrees C

Table 3.3: Packaging Requirements for External Components of Board

Packaging Requirements	
LCD Display	Displays output voltage to .01 accuracy
LEDs	Turns on/off depending on which input is connected
Cooling Fan	• Fan turns on when above 70 degrees C • Microcontroller (arduino) controls temperature probe to turn on fan
Circuit Protection	• Circuit shuts off when current exceeds 13A • Circuit shuts off when voltage exceeds 27V

The MISO needs a packaging device in order to make it aesthetic and marketable. This will also help with its portability so that users are not held back by the circuit. Ideally, the package will have the MISO enclosed with inputs and outputs easily accessible. On the surface, there will be an LCD screen that will display the input and output voltages that are currently being read. This will help the user in determining which inputs are being used and at what rate. A sample schematic is below.

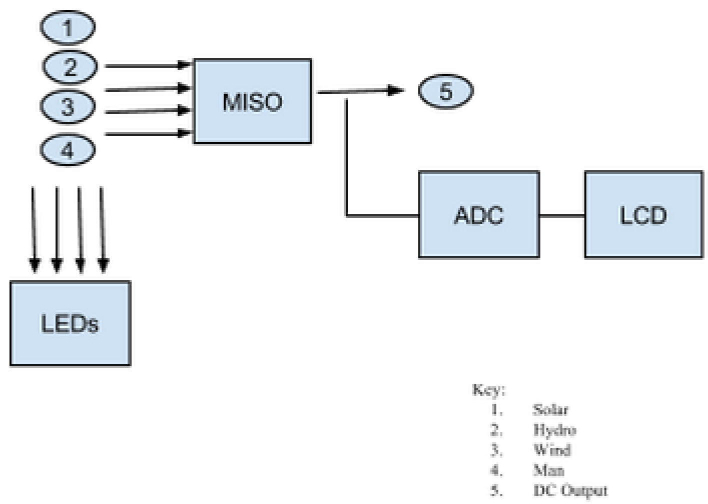

Figure 3.4: Display Configuration

Chapter 4 (Design)

In this Chapter, the design of the MISO will be discussed. The initial design was performed previously by a graduate student at Cal Poly. The design serves as the starting point for this project. Modifications from this initial design will be described.

Initial MISO designed

The initial MISO converter design consists of three stages: Input Stage, Power Stage, and Controller Stage as depicted in Figures 4-1, 4-2, and 4-3 respectively.

Individual Input Stage:

Figure 4-1 shows the input stage to the MISO for each individual input. As shown, the input stage utilizes a series MOSFET with internal diode. When multiple inputs are being connected to the MISO, the diode in each input stage functions like an “OR” diode. This means only an input source that has the highest instantaneous voltage will provide the power to the MISO.

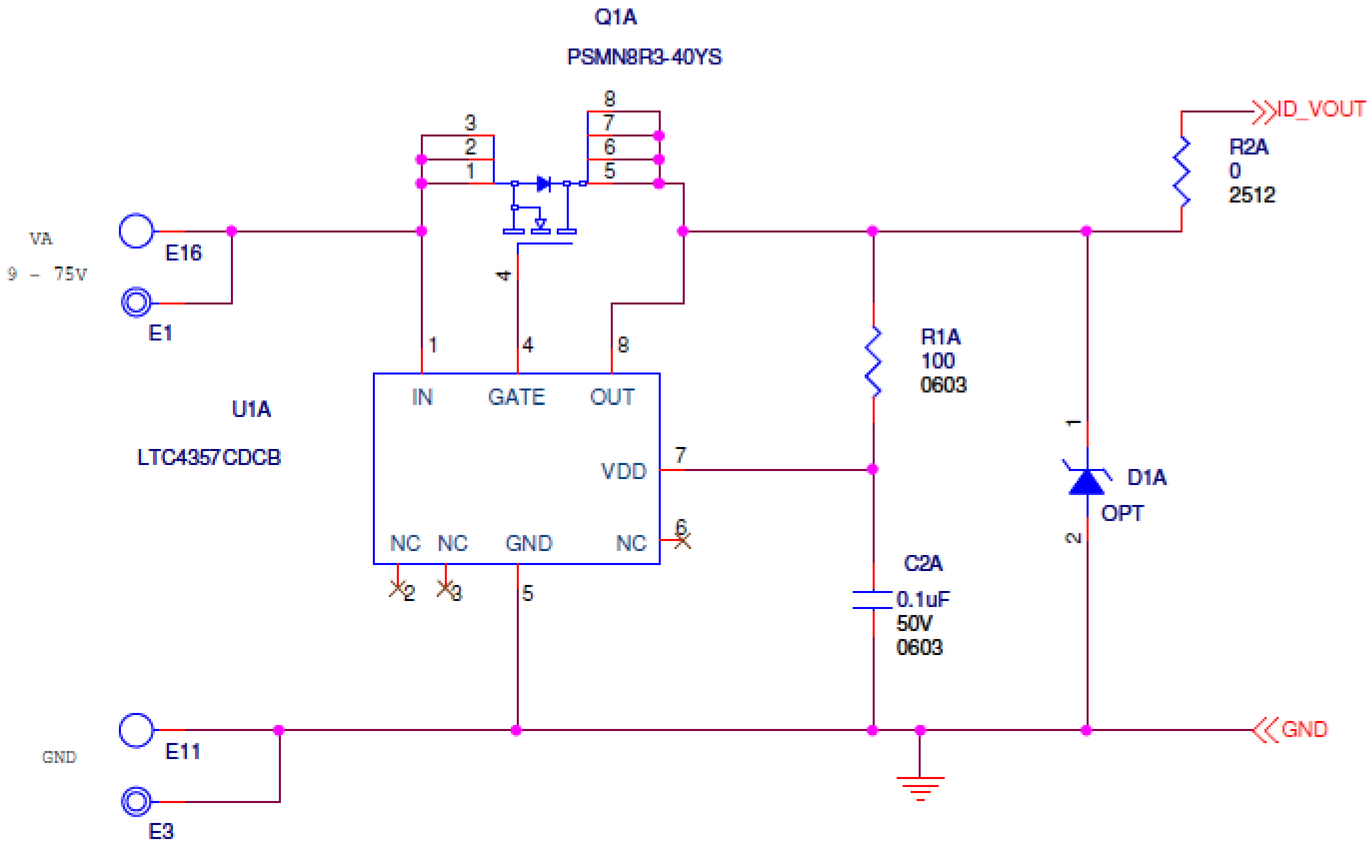

Figure 4. 1: Input Stage of MISO

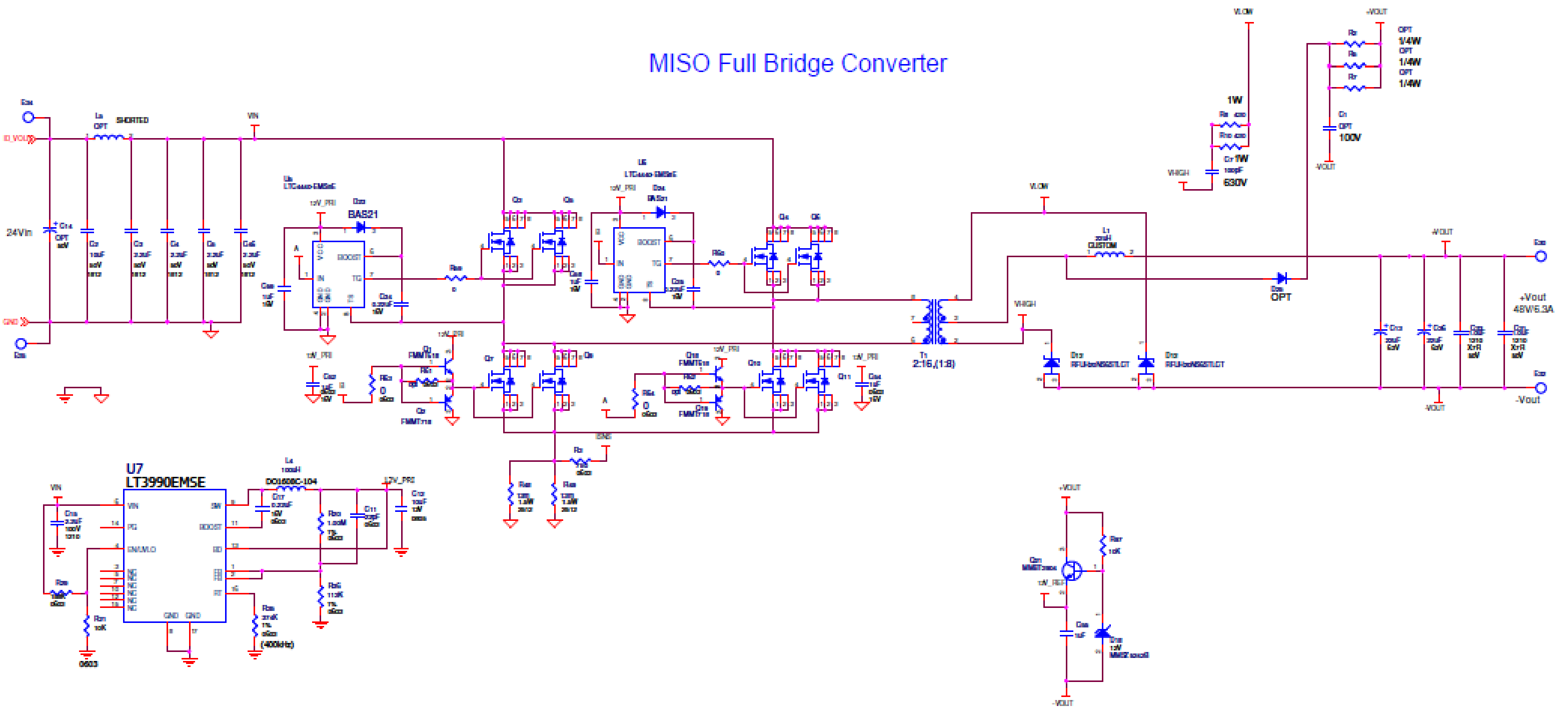

Figure 4. 2: Power Stage of MISO

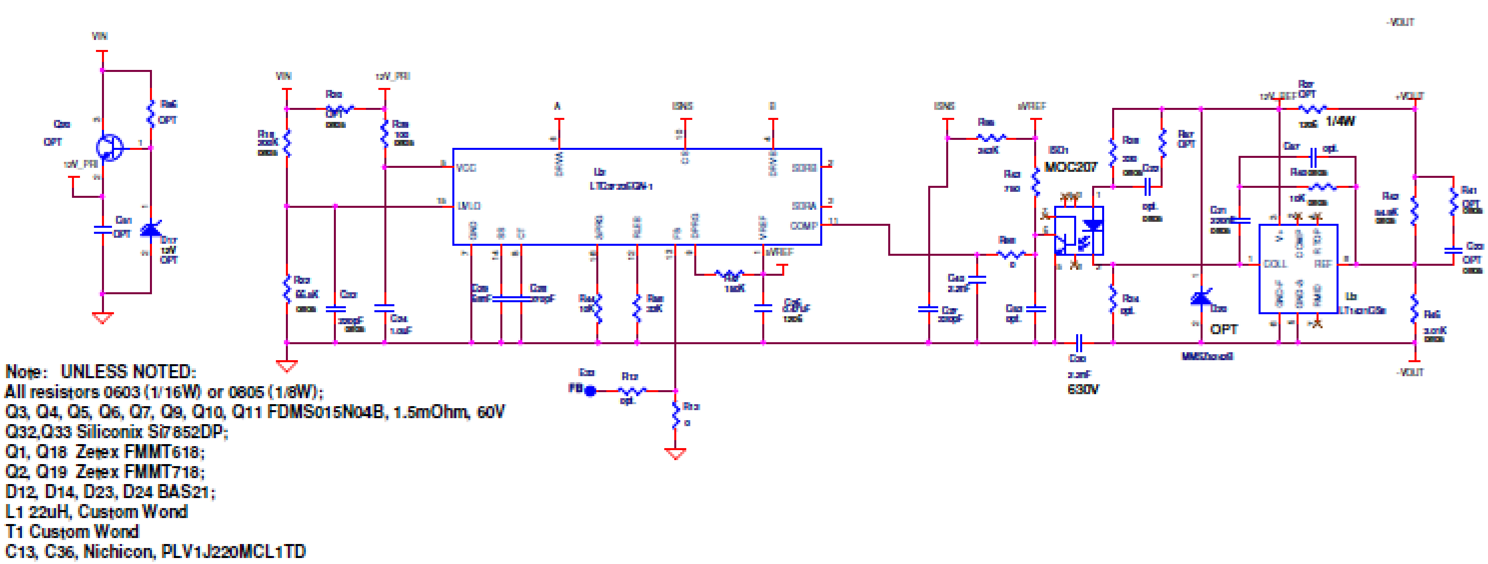

Figure 4. 3: Controller Stage of MISO

The power stage employs the Full Bridge topology which was chosen based on the amount of power handled by the MISO (600W max). The following details the functionality of the MISO converter.

How it works: The MISO is broken up into essentially two separate sections: the power line and the controller line. The power line consists of eight MOSFET switches that create a pulse to enter the transformer. The switches alternate in sending +24V and -24V to the transformer. The output of the transformer is 48V.

The eight MOSFETs are being controlled through the controller chip LTC3723EGN-1 (U2 on the schematic). MOSFETs Q3, Q5, Q10, and Q11 are sent roughly 5V from the controller chip (labeled as ‘A’ on the schematic). Similarly, Q4, Q6, Q7, and Q9 are sent the same 5V from the controller chip; however, it is sent 180 degrees out of phase, allowing only half of the switches to be on at any one time.

A step-down buck IC, LT3990EMSE, takes the 24V from the input and steps it down to 12V. This 12V is what powers the rest of the ICs on the board.

The output stage contains regulation components to ensure the output remains a steady 24V. Because this circuit is operating at very high frequencies (roughly 250kHz), fast recovery diodes are necessary in order to maintain DC characteristics. Similarly, output capacitors C13, C36, C33 and C31 are necessary to ensure the output voltage is held constant.

Problems with initial design:

The original MISO circuit functions correctly. With a 24V input, the output receives 48V. However, the custom components used (Transformer T1 and Inductor L1) make this circuit difficult to reproduce and thus become a marketable product.

Similarly, because this circuit was designed to simply work, safety precautions were not taken in order to prevent circuit destruction. Therefore, TVS voltage protection diodes as well as fuses are installed. There will also be a fan designed to turn on when the heat of the circuit reaches too high of a temperature.

Final MISO Design

Figure 4-4 shows the final board layout of the MISO design. Because the original layout and design was operational, the focus on the new design was optimization and safety. Protection devices were added to the input to prevent overvoltage or overcurrent from destroying the circuit. TVS diodes were placed across the input and would prevent voltage from passing if the voltage ever exceeded 27V. Similarly, onboard fuses were placed and will prevent current from flowing if the current ever exceeded 15A.

Another issue with the initial MISO design was the temperature of components would get too hot during operation. To solve this issue, a thermistor IC was placed on the board and connected to an external fan. The external fan is designed to turn on when the circuit temperature hit 70 degrees Celsius.

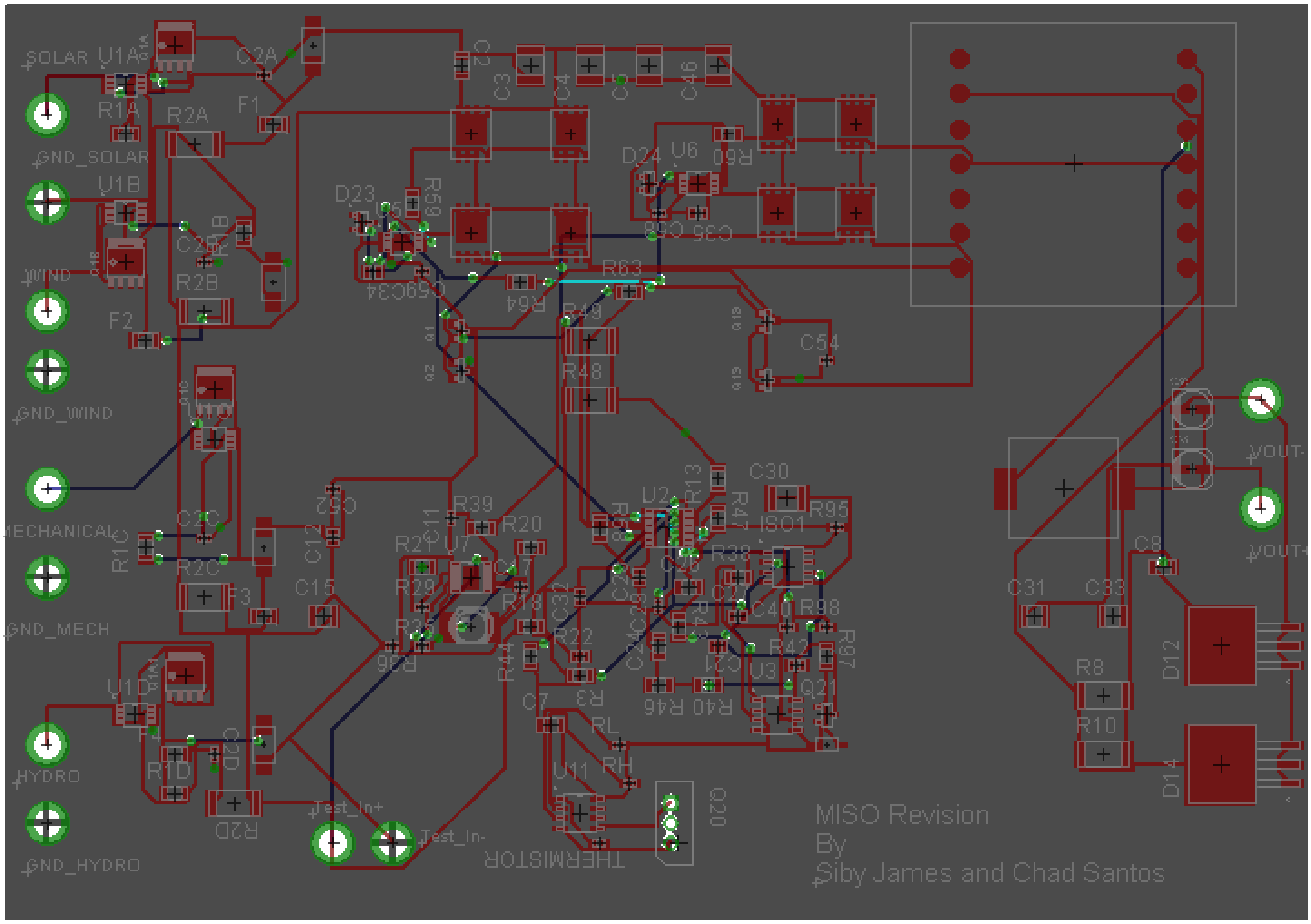

Figure 4. 4: PCB Layout of MISO Circuit

Transformer T1 Replacement:

The original transformer, though completely functional, is custom wound and thus hard to reproduce. Also, because it was custom wound, it was very large and difficult to work around. In choosing a transformer that is commercially available, the MISO will be easier to reproduce and can be readily available for customers. Therefore, we chose to replace the custom wound transformer with the 750310355 transformer. The parameters for this transformer can be seen in Table 4.1.

Figure 4.5:: Picture of transformer used in circuit

Table 4.1: Table detailing the characteristics of the transformer used in the circuit

Model	750310355 Wurth Electronics
Primary Voltage	18-30V
Turn Ratio	1:10
Continuous Current	24A
Inductance	2.5µH

In the previous design of the MISO Converter, the inductor was found to heat up to an unsafe temperature. In order to correct this, a custom wound inductor was placed in the place of the inductor and was found to work at a safer temperature. Although this solution worked, it was necessary to find a commercially available inductor in order to make the MISO more reproducible. This inductor fulfilled the requirements that the custom wound inductor did should work well.

Inductor L1 replacement:

Figure 4.6: Image of inductor used in MISO design

Table 4.2: Table detailing the characteristics and description of Inductor

Model	SRP1265-470MCT-ND
Inductance	47 μH
Peak Current	6.5A
Resistance	90MΩ

Transformer Test:
The original MISO called for a 1:8 transformer, but this was custom wound.

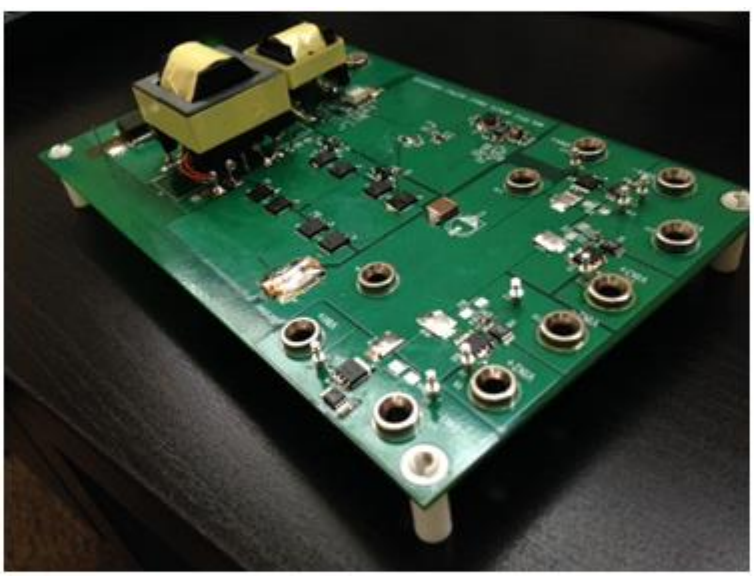

Figure 4.7: Image of original MISO with custom wound inductor and transformer

As seen in Figure 4.7 above, the custom wound transformer is very large and does not fit on the pads provided. Commercially available transformer are much more consistent in that footprints and pads are already provided for it. This allows for easier PCB design.

It was decided that a 1:10 commercially available transformer would work as well. Though the original design used a 1:8 turns ratio, the benefit of having a commercially available 1:10 transformer outweighs the benefits of using the exact 1:8 transformer. It was determined that the difference in turns ratio would make the output in the low 50V range instead of the desired 48V. Tests to ensure the transformer worked at 250 kHz are below.

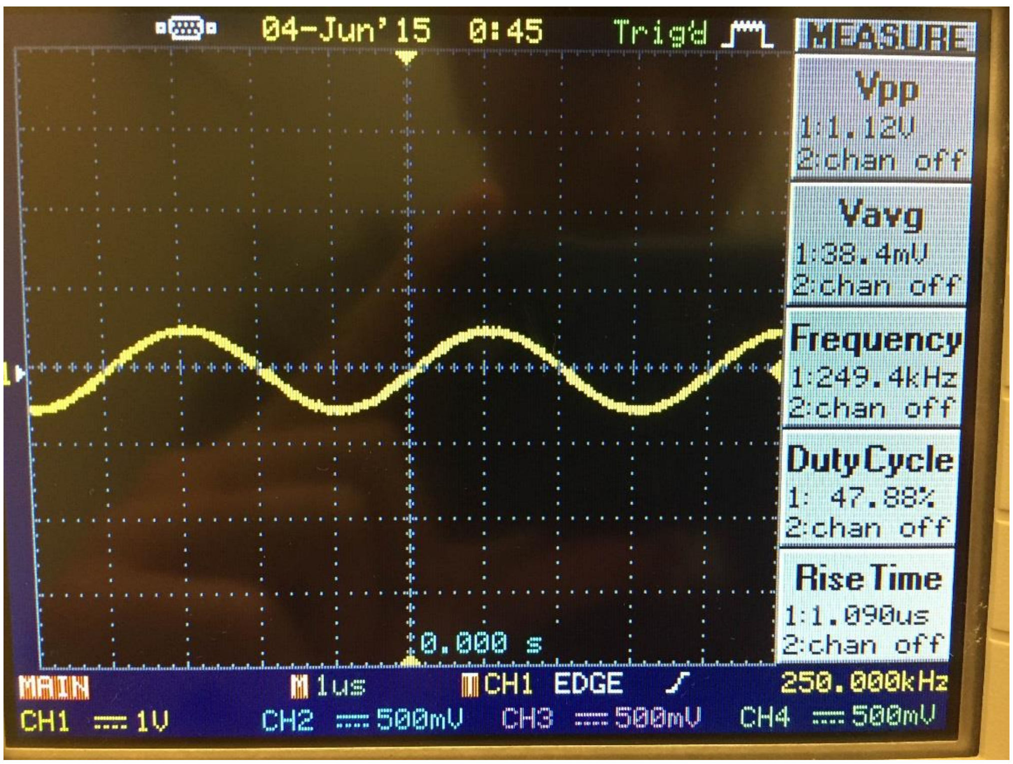

Figure 4. 8: Input of transformer at 1V

Figure 4.8 displays the input of the transformer when applied with a 1V sinusoidal wave at the frequency of operation, 250kHz.

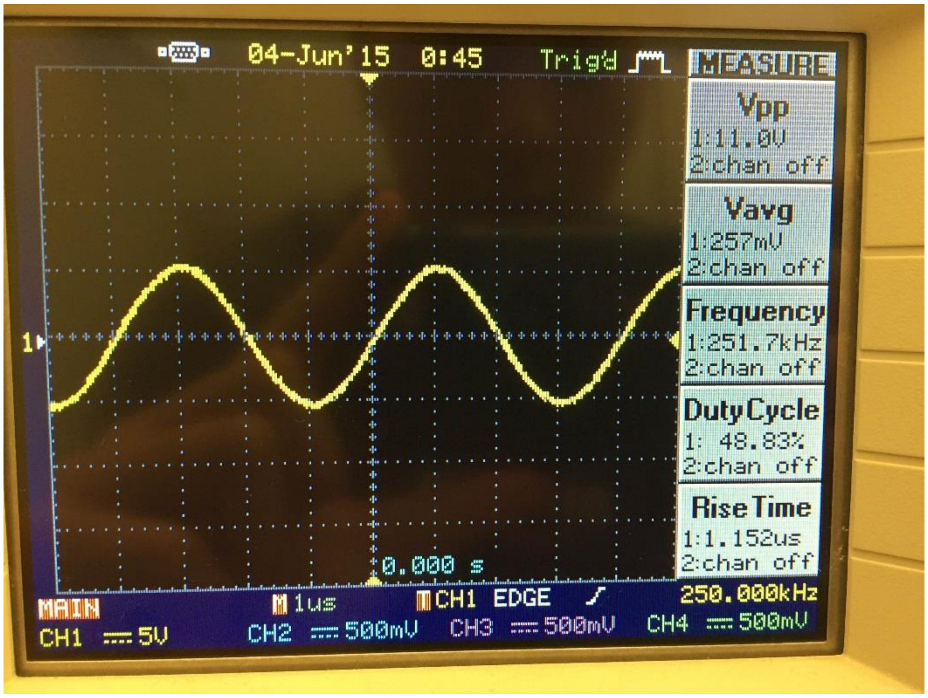

Figure 4. 9: Output of transformer at 10V

Figure 4.9 shows the output of the transformer at 10V. This shows that the transformer's 1:10 rating works as it should and confirms the reliability of the transformer.

<u>Chapter 5</u> - Results

Figures 5-1 and 5-2 show the resulting MISO boards for revision 1 and 2 respectively. Two separate circuit layouts were used. The layout design was done using Eagle Professional. The first board was constructed to "test" the circuit to determine if individual component was functioning. The second board was built as a result of optimization of the layout to yield a reduced board size as well as to combine all the separate aspects of the board. The functionality of the circuit was then tested and problems within each section were also analyzed and debugged as discussed later in this chapter.

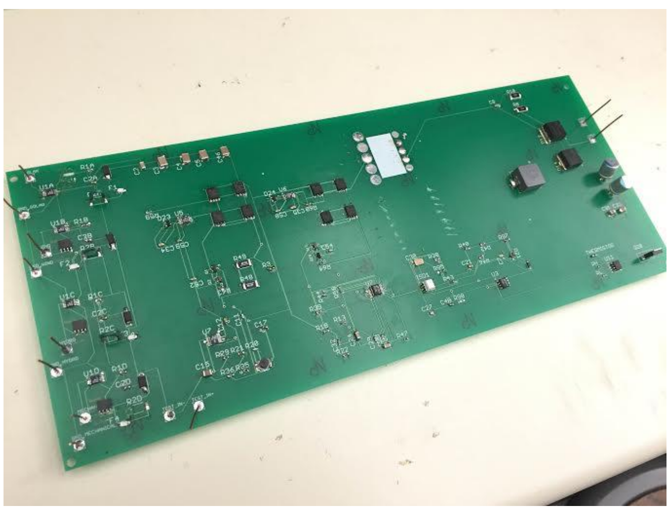

Figure 5. 1: MISO Revision I

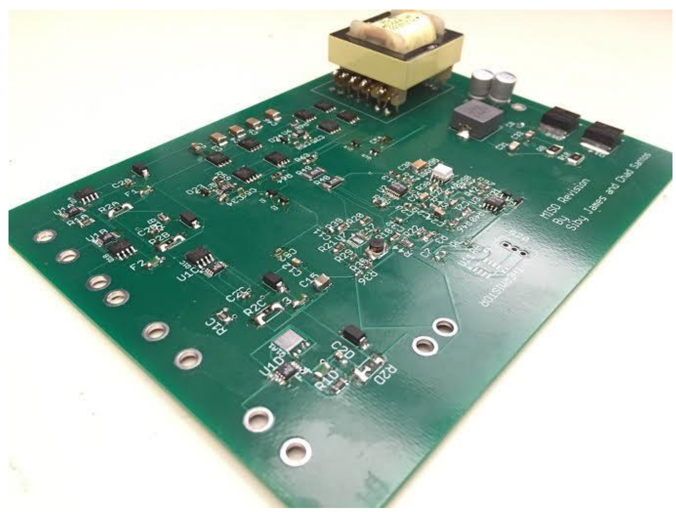

Figure 5. 2: MISO Revision II

Input Power to Board:

The first test run on the MISO was to determine whether or not power was being supplied from the inputs. A 24Vdc input voltage was supplied to each input, and the input voltage was probed at the input capacitors to verify that it was receiving the 24V. Initial tests proved invalid, as 0V was being transferred to the input. Later it was found that the TVS, transient voltage suppression, diodes placed on the board at the input stage were not connected correctly, thus shorting any positive voltage appearing across the input terminals. The TVS diodes were placed in order to protect from over voltage going through the circuit. Once these diodes were connected properly, the 24V began to transfer over across the input voltage. Figure 5.3 below shows the input of the MISO properly displaying 24V. The voltage was probed after the input capacitors to ensure DC functionality is still maintained.

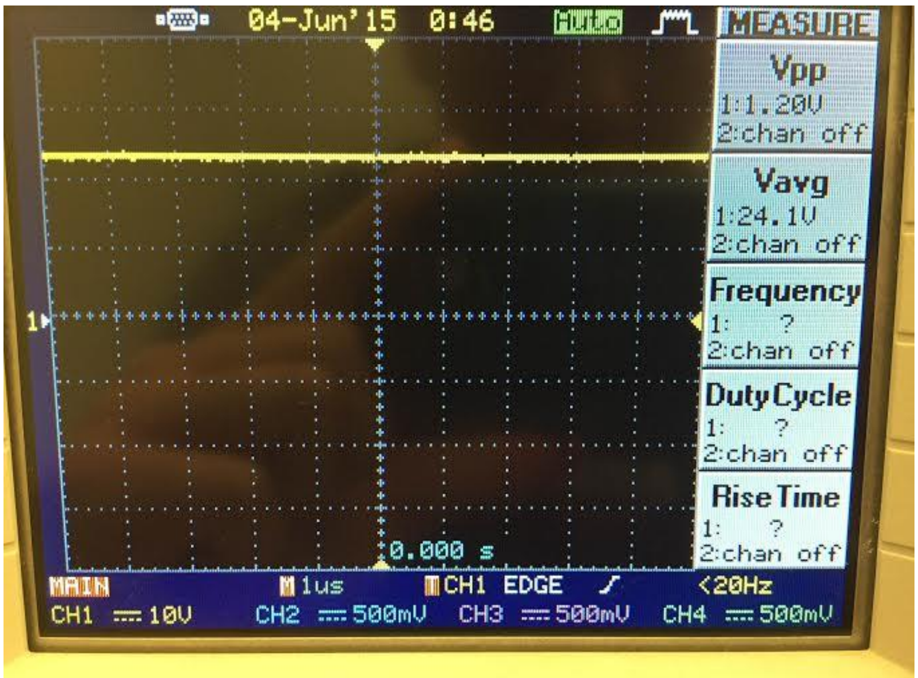

Figure 5.3: 24V Input Voltage Probed at Input Capacitors

Test for MOSFETs Switching:
In order for the MISO to function, the MOSFETs must be switching accordingly. Each MOSFET output/gate should be switching at a 50% duty cycle, swinging from 0V to roughly 10V. However, when tested, the gate and the source of each MOSFET were each outputting roughly 10V, thus making the switch shut non-operational. A fully operational switch has a gate voltage that is higher than its source. When the switch voltage is the same or grater than the gate, the switch turns off.

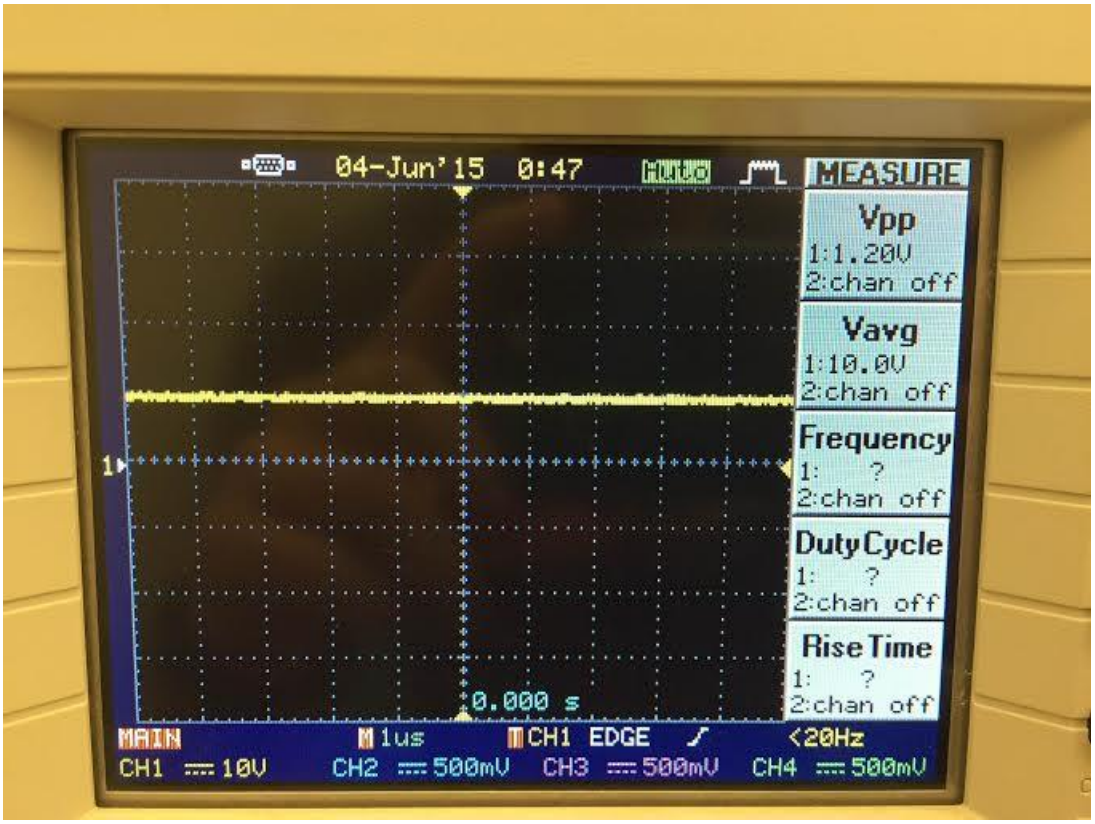

Figure 5.4: Voltage at both gate and source of MOSFETs

After further investigation, it was found that one pins of the driver ICs (LTC440-EMS8E labeled U5 and U6 in the schematic) were shorted. Once this was fixed, there was 0V found at the gate and source of the FETs. The gate voltages of the low side MOSFETs were then tested to determine whether or not the switches were blown. Because the gates of the low side switches were also 0V, it was determine that the driver/controller were not sending the correct signal.

Outputs ‘A’ and ‘B’ were probed on controller chip U2 (LTC3723EGN-1) to see if they were outputting both the correct voltage and at the phase. U2 is a synchronous push-pull PWM controller for isolated power converters. Pins A and B represent driver pins that are connected to the MOSFETs' gates of the MISO. Driver A is sent to one high side and low side FET, while Driver B is sent to the other high side and low side FET.   Ideally, both would be around 5V and they would be 180 degrees out of phase. By switching 180 degrees out of phase, a positive square signal and a negative square signal can be produced from the switches. However, both pins were outputting a constant voltage of 5V (no switching) as seen in Figure 5.5.

In the attempt to debug the controller chip (LTC3723EGN-1 labeled U2), it was found that the chip was no longer receiving any power. In fact, it was found that none of the other ICs were receiving the 12V needed to power the chip. Therefore, the next step was attempting to debug the buck converter that sends each chip the 12V needed for power. It was determined that the input and output capacitors of the buck regulator chip (LT3990EMSE) were not close enough the step-down chip in order for stable conversion of 12V. Also, the boost and switch pins of the buck regulator chip (LT3990EMSE) ideally are alternating signals. However, when debugging, the pad that was supporting the boost pin of the buck regulator chip melted off, thus making the chip and thus the rest of the board, non-operational.

Figure 5.5: Output Voltage of Controller Chip - constant 5V

Figure 5.5 above shows the output of the driver pins of the controller chip LTC3723EGN-1. It is displaying a constant 5V, when ideally it should be switching.

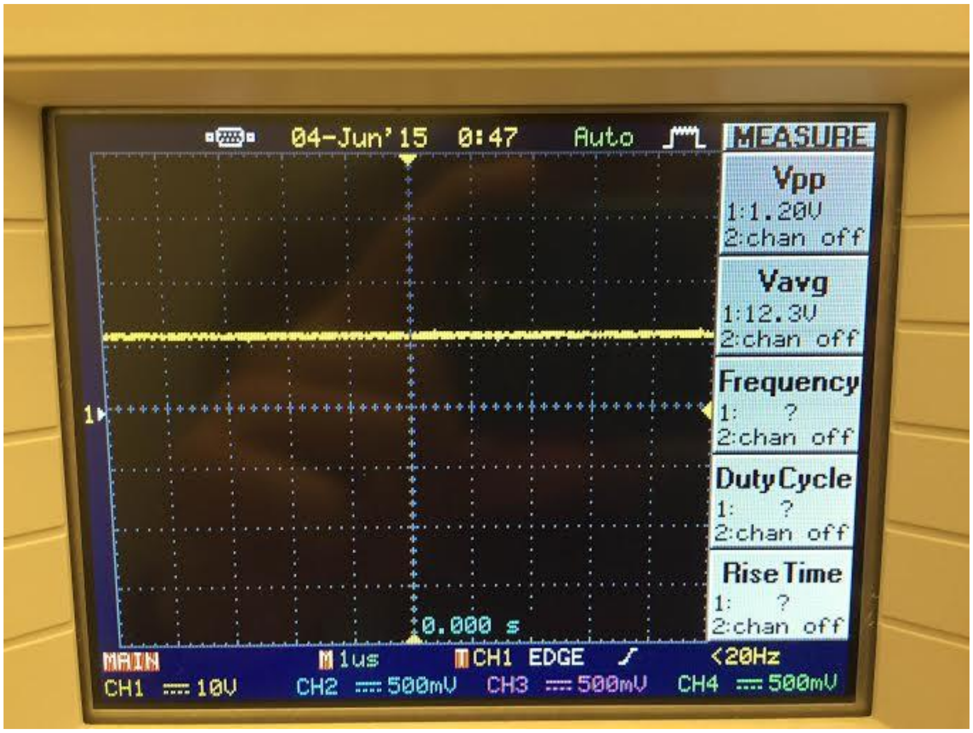

Figure 5.6: 12V Output of Buck Converter

Figure 5.6 above displays the output of the buck converter LT3990EMSE when it is functioning correctly. However, it was no longer outputting this signal, as it was outputting zero volts.

Table 5. 1: List of Problems with Solutions

Problem	Solution
Board not receiving correct power	Remove TVS from all inputs. Only working input is the fourth (bottom) input
High side switches not switching (gate and source voltage are the same). Both were 10V	Connections not soldered on correctly after probing with multimeter.
Gate and source voltage of high side switches are both 0 V	Further debugging of switches.
Low side switches have 0V on gate, drain and source. (possible switch is broken)	Further debugging - probe driver and controller chips associated with switches.
Driver chips voltage outputting same voltage entire time (about 5V) - not switching	Replaced chips.
High side driver on right side (U6) needs external 12V power supply. Tracing not correct.	Soldered on wire to power pin. Should redesign schematic.

Left side high driver shorted when being probed. No longer able to receive power.	Replaced chip.
Trace back to U7, controls power for high side drivers. U7 not receiving the correct 12V output. Input capacitors should be closer to pins of IC	Redesign traces and move capacitors closer to input and output of chip.
No Power to any IC. Buck Converter no longer operational (boost trace fell off)	Order boards from new PCB manufacturer - not Pentalogix

As we stepped through the problems of the MISO Converter, we found that a lot of issues occurred. We realized that we needed to handle all of these problems from their source. When probing with the oscilloscope we were able to find the areas where there were problems. By creating this table we were able to keep track of the decisions that were made when solving these problems.

Chapter 6-Conclusion

The DC House Project with the MISO circuit provides an alternate solution for rural areas that do not usually have access to electricity. By incorporating the four renewable energy sources, solar, wind, water, and human-power, the project allows for the house to have several options of electrical energy rather than relying on grid power. The MISO converter is at the heart of the project with output voltage of 48V at 288W maximum power rating. In this project, several revisions to the MISO converter boards have been conducted. However, the MISO was only functioning partially due to technical issues which most likely occurred in the production of the board. The following will provide instructions and suggestions on ways to test and manufacture the board in order to minimize errors and produce a functioning MISO circuit.

In order to produce a MISO circuit that outputs 48V it is necessary to breakdown our overall circuit into two parts, the full-bridge DC-DC Converter and the controller. Before any of those can function, it is necessary that all the ICs that are powered by 12V receive 12V from the 24V input by stepping it down through a Buck Converter. Once this voltage is stepped down it is necessary to confirm this by testing. Without the 12V supplying the ICs of the MISO, there will be no power to the DC-DC converter and controller stage. The next stage to verify and test is the controller stage. Once assembled, look to see that the nodes labeled “A” and “B” are outputting pulses that are 180 degrees out of phase. These pulses are responsible for the MOSFETs in the full-bridge to switch and provide an AC wave to the primary side of the MISO transformer. With these specific directions in testing, it should give the user a better idea of what to look for. Another source of error comes from the software and manufacturer used.

When producing both versions of the MISO, we chose to use eagle layout software and pentalogix as our PCB manufacturer. When using eagle, it is extremely straightforward; however, it is quite difficult to use the software given the amount of components that have to be used on the MISO circuit. It would be more useful to utilize a program that is not free and that has much more design capability and flexibility than eagle. An example of this is PADs PCB. Another suggestion would be to use Advanced Circuits due to their student discounts and flexibility and reliability of boards.

When working with the components for each board, it was extremely difficult to solder the ICs with many pins. A solution to this problem would be to have this board go through a reflow oven to mount all components as this would save a large amount of time and effort. Some components were easy to solder, while others were extremely difficult. This should be considered when choosing resistor sizes and IC packages.

With all of these suggestions in mind and designs provided, a fully functional MISO converter in a small footprint can be achieved.

Appendix D - Analysis of Senior Project Design

Design of a Mulitple Input Single Output DC-DC Converter for the DC House Project
Siby James, Chad Santos
Advisor's Name: Taufik

1. Summary of Functional Requirements

   Describe the overall capabilities or functions of your project or design. Describe what your project does. (Do not describe how you designed it).

   i. The MISO Converter is a multi-input single output DC-DC converter that will allow the conversion of four renewable energy sources from a 24V input to a 48V output.

II. Primary Constraints

a. Describe significant challenges or difficulties associated with your project or implementation. For example, what were limiting factors, or other issues that impacted your approach?

i. The biggest challenge that was encountered with this project involved understanding the schematic and finding the exact components that related to the schematic, since the schematic was created a few years ago as a master's student project. Since a bill of materials was not provided with the schematic, it was necessary to go through the schematic and find the components that matched the ratings provided on the schematic. For example, there is a transformer that did not have any information presented on the schematic. It was necessary to contact the creator of the MISO converter schematic in order to find out that it was not purchased, but made. Another difficulty for this project comes from the design of voltage and current protection due to lack of experience with PCB design.

III. Economic

a. What economic impacts result?

i. Human Capital: The development of the MISO Converter and installing this into the DC House on campus and Indonesia will allow for similar houses to be created and provide energy to low income neighborhoods. Another advantage is the low cost by using renewable energy sources.

ii. Financial Capital: Profit can occur only if a company decided to bring this product on as a commercial product to be sold to homeowners. Once the company begins to manufacture the MISO converter it will take some time for the boards to be created and then attempt to make a profit on the product. The company would need to pay the creators for the design and may only make profit once the costs for design is completed.

iii. Natural Capital: The device would consist of ICs created from silicon and plastic. The idea of renewable energies as a source of energy for the DC House will allow for sustainable energies to be used.

iv. Costs: A majority of the costs comes from the production of the MISO Converter. There are almost a hundred components used to create the MISO converter. Another major cost of the project comes from the PCB manufacturing. The estimated cost of components coming from Digi-key for five boards is about $200 and the estimated cost of manufacturing five boards is about $200 resulting in an estimated cost of $400 to produce enough units for this project.

Item	Number	Company	Cost
Full Bill of Materials	1	Digi-key	$898.08
Custom PCB Boards	5	Pentalogix	$914.69
		Total	**$1,812.77**

IV. If manufactured on a commercial basis:

a. Estimated number of devices sold per year: Approximately 100 MISO Converters
b. Estimated manufacturing cost for each converter: Approximately $200
c. Estimated purchase price for each device: $500
d. Estimated profit per year: $30,000
e. Estimated cost for user to operate device, per unit time: $1000/year

V. Environmental

a. The environmental impact of the MISO converter comes from the fact that the MISO utilizes four different types of renewable energy sources. The use of renewable energy sources has become so common within suburban households and even company buildings that the MISO Circuit will be an optimal choice in converting these energy sources to consumers. With the new obsession by major companies to be environmentally friendly, the MISO Circuit will appeal to them and become more popular and profitable. The device (PCB and components) has to be recycled properly according to electronics' disposal regulations to maintain sustainability. Failure would mean that these components could release toxic chemicals into the environments and affect animals and humans.

VI. Manufacturability

a. In order to manufacture the MISO Converter it will be necessary to buy components from Digikey and order PCB layouts after completing our design. This process will take much longer than usual with two people producing five boards since each component will need to be soldered manually. If this process is automated the manufacturing of this product will be increased exponentially and more units can be produced.

VII. Sustainability

a. Describe any issues or challenges associated with maintaining the completed device, or system.

i. Due to schematic of this project being provided before starting, it was much easier than anticipated to lay out the board and add the necessary protection circuit, fan circuitry, and LCD display circuitry. The major issues that we have run into so far involve our custom inductor and custom transformer. It is extremely impractical to produce units with custom inductors and transformers. The reason custom inductor and transformer were used was to facilitate the peak currents used and since any commercial components did not yield the same output results needed.

b. Describe any upgrades that would improve the design of the project.

i. Upgrades that would improve the project could include optimizing the PCB layout by utilizing the space efficiently. Other options would be to take out unnecessary components that do not need to be implemented into the design.

c. Describe any issues or challenges associated with upgrading the design

i. A major issue that comes with upgrading any design comes with the amount of time that is used and the amount of effort placed into the design and finally the benefit. Most of these improvements that are being implemented help the overall function of the MISO converter and allow for the circuit to become more efficient overall.

VIII. Ethical

a. Describe ethical implications relating to the design, manufacture, use, or misuse of the project. Analyze using one or more ethical frameworks in addition to the IEEE Code of Ethics.

i. A positive ethical implication as a result of the use of the MISO Circuit comes from the renewable energy. This will promote the idea of using renewable energy sources as a viable option within houses. As a result of doing so, the ethical impacts of using energy coming from a utility will be reduced. When it comes to the IEEE code of Ethics several ethical problems could arise from the manufacturing and completion of the project. A major ethical problem that could possibly occur comes from the possibility of finishing this product until it works first. If this were to occur, it would be highly unethical to finish the project without checking to see for errors.

IX. Health and Safety

a. Describe any health and safety concerns associated with design, manufacture or use of the project.

i. A health/safety concern stems from the voltages associated with the MISO circuit. Although this is a great use of renewable energy, there is a great amount of risk that comes from the high voltages and current that moves through the converter. The homeowner must take the proper precautions when taking care of the area that houses the MISO converter.

X. Social and Political

a. This project directly impacts any consumer of solar energy or any other renewable energy source. Also, this project indirectly impacts anyone who uses regular energy sources from utility companies. This impact comes from a sustainable approach to consuming energy in commercial housing. The results from this change in energy provides a clean and cheaper form of energy. As the MISO Converter becomes a more popular converter, more will become aware of the benefits of renewable energy and will purchase the MISO Converter. The only political ramification would come from the constant struggle between renewable energy users and those who consume energy through utility companies.

XI. Development

a. Describe any new tools or techniques, used for either development or analysis that you learned independently during the course of your project.

i. An interesting observation formed from designing the MISO circuit is understanding the flow of current and how all the voltages are being stepped down throughout the circuit. While devices have already done stepping down, it is amazing to see that there are four sources being stepped down to being utilized at greater than 80% efficiency.

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